

APPROVED FOR
RELEASE DATE:
15-Jul-2011

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CIA/RR GP 60-100:L

BRIEF

EXPLANATION OF GEODETIC TARGET ERROR FOR THE ICBM
IN RELATING LAUNCH AND TARGET POINTS
ON DIFFERENT CONTINENTS

Introduction

Recent ICBM tests by the United States have demonstrated a capability of impacting nosecones within less than 2 nautical miles of a designated target. A significant factor contributing to this accuracy -- and its calibration -- was the accuracy of the geodetic positional relationship established between the launch and target points, in which the error amounted to ± 500 feet. Unfortunately, the US currently can attain such geodetic accuracies only for European USSR. This paper explains in brief nontechnical terms the nature of the geodetic problem and the efforts being made to improve currently inadequate geodetic positioning.

A. The problem of intercontinental geodetic inaccuracies arises from the diversity of geodetic systems and difficulties of interconnections across the oceans.

1. Continental systems of geodetic control end abruptly at coast lines.
2. Gaps in geodetic control across ocean areas create uncertainty in positioning of the continents.
3. The large geodetic nets of the world are based upon different datums.*
4. The US uses the North American Datum, adopted 1927; the USSR uses the Pulkovo 1942 Datum, adopted in 1946.
5. Datum differences give rise to errors in computing distances and directions between widely separated launch and target points.

* See the Annex for explanation of the basic elements of the geodetic problem.

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6. Ultimate target accuracies depend on availability of identifiable geodetic points to which targets must be related.

B. Geodetic errors develop because the earth is not a true sphere but an irregular figure flattened at the poles and having a bulge near the equator.

1. Size and shape of the earth: Estimates of semi-major (equatorial) axis and polar flattening have varied widely, causing differing discrepancies in the fitting of an ellipsoid to the geoid (generalized undulating sea-level earth surface).

2. Orientation of ellipsoids: Ellipsoid axes do not coincide with the earth's axis of rotation, thus making positions of different geodetic systems not directly comparable for geodetic computations.

3. Errors due to deflections of the vertical: Such errors result from angular differences between observations that are vertical to the geoid and computed as perpendicular to the displaced reference ellipsoid.

C. Insufficiency of Soviet geodetic data and large-scale maps causes a significant US disadvantage in the accurate location of targets.

1. Systematic geodetic data on USSR are unavailable for the area east of Leningrad, Gor'kiy, and Novosibirsk. This prevents the production of accurate maps or the use of aerial photography for computing target locations.

2. Modern large-scale maps are lacking for vast areas east of Gor'kiy and the Caspian Sea.

3. Map error is determined by the scale of available maps. The error is negligible if an area is covered by maps at the scale of 1:100,000 or larger, but the error becomes significant, particularly for locating Soviet ICBM sites, for areas covered at scales of 1:1,000,000 or smaller.

4. Gravity anomalies have an effect on missiles during flight.

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D. Comparative estimates of US-Soviet geodetic target error over a 5,500-nautical-mile range show a US disadvantage.

	<u>*US Against USSR</u>	<u>**USSR Against US</u>
1. Error due to uncertainties in size, shape of ellipsoid, and target uncertainty	1,000 feet or less to 2n. miles	1,000 - 2,000 feet
	a. 1,000 feet or less applicable against preselected targets in European USSR	
	b. 2 n. miles applicable against Soviet launch sites with locations still to be ascertained	
2. Map error, varies with scale of available maps	200 - 2,000 feet	100 - 500 feet
3. Gravity error	500 - 2,500 feet	500 - 2,000 feet
4. Estimated over-all geodetic error		
Average instance		0.3 - 0.6 n. mile
a. For 90 percent of European USSR targets	Within 1,000 feet	
b. For remainder of USSR		
50 percent certainty	2,000 feet - 1 n. mile	
90 percent certainty	4,000 feet - 2 n. miles	

* Simplified rounding of representative estimates provided by US Army and Air Force sources.

** ORR estimates evolved from extensive studies of Soviet geodetic capabilities and programs and consultations with US military and civilian geodesists; differences between US and USSR based on advantage accruing to the USSR as a result of withholding maps and data.

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E. US programs to improve geodetic accuracies are particularly necessary to support greatly improving future weapons systems. [Present geodetic requirements are $\pm 1,000$ feet; current projections are ± 500 feet (1965), and ± 250 feet (1970).]

1. Scientific programs to reduce geodetic error are currently in operation or planned.

a. Different national geodetic systems on different ellipsoids, which were connected after World War II into continental systems (European, Tokyo, North American), were later connected into single world systems by the US Army and the Air Force. Recently, these two have been reconciled to form a single Defense World Geodetic System. This system, however, represents only a first approximation. Additional programs are mandatory for its refinement and verification.

b. IGY lunar photography program has been initiated. Results are expected in 1 to 2 years.

c. HIRAN (high-precision Shoran) has been used for intercontinental ties. The results have reduced the uncertainty of connections between Europe and North America to about 240 feet; uncertainty still exists because of weaknesses in Canadian geodetic positions established by Shoran methods.

d. World gravity survey is still under consideration, including oceanic coverage. Surface-ship and airborne instrumentation are now being tested and will reduce cost and speed up completion of the survey.

e. Earth-satellite observations and orbit analysis give promise of intercontinental ties, with ± 100 -foot accuracy expected by about 1965.

f. High-altitude rocket-flash programs are now in planning for determining three-dimensional coordinates between continents, giving positions free of deflection-of-the-vertical errors.

g. Reconnaissance-satellite photography may within 5 years yield the most direct and accurate checks on intercontinental positions.

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2. Collection of Soviet large-scale maps and geodetic data are essential for identification and accurate positioning of targets, especially in the Urals and throughout Siberia.

a. Soviet maps (1:100,000; 1:50,000; 1:25,000) and geodetic data have been sought unsuccessfully since end of World War II. Collection of such materials has now been made a top priority target to fulfill a First Category Priority National Intelligence Objective (para. f); coordinated clandestine effort is being markedly increased. The yield to date is 13 East German map sheets at 1:25,000; 102 additional sheets have been obtained through chance events (defections).

b. Efforts made at international scientific meetings to secure data have met with no success to date.

F. The USSR holds a comparative advantage over the US.

1. Whereas the competence of US and USSR geodesists is generally comparable, Soviet geodesists are possibly superior in the field of theoretical gravity and number of trained personnel.

2. USSR has vastly greater number of trained geodesists for future use in missile operations.

3. Soviets have geodetic targeting advantage over the US, resulting from a policy of withholding information from the West.

a. The Soviet policy of withholding topographic maps has been particularly effective. As a result the all-purpose postwar Soviet series at 1:100,000 is unavailable. All large-scale maps available to the US are of pre-1940 date. Coverage is limited, almost entirely lacking for Siberia and the Urals.

b. Because of the Soviet withholding of all gravity and geodetic data since the revision of the Soviet geodetic system in 1946, available data are all on the old Pulkovo 1932 system, none are on the new Pulkovo 1942 system. The USSR, however, has uncontrolled access to geodetic data for the US.

4. The USSR method of projecting points perpendicular to the ellipsoid of reference provides more rigor and promises greater accuracy in the joining of the Soviet systems to other geodetic and mapping systems.

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ANNEXBASIC ELEMENTS OF THE GEODETIC PROBLEMA. Origin of the Problem1. Geodetic Systems End at Coast Lines

Ground control points on the Earth's surface conventionally are established by measurement from a pre-selected initial point to other points by means of triangulation (distances between points of triangles are calculated through the measurement of angles). Since this procedure is impossible over ocean areas, continental geodetic systems stop at coast lines. Limited ocean spaces can be covered by direct measurement of sides of triangles (trilateration) from continent-to islands-to continent, using electronic techniques. This is called HIRAN. Europe has been tied with North America through Canada with an estimated uncertainty of ± 240 feet. Such ties were made in the Far East and are now being undertaken to interconnect Australia, New Guinea, the Marshalls, and other islands farther east. No HIRAN connection between the Tokyo and North American datums is possible.

B. Source of Errors1. Size and Shape of the Earth; Datums

Computing relationships of control points for small areas (property surveys) is easy because computations are made on a plane surface. For large areas where earth curvature is involved, however, computations are made on a curved surface of a near-sphere with pre-determined dimensions. Such a figure, the ellipsoid of reference, has definite estimated lengths of the equatorial and polar axes and a ratio between the two that defines the flattening. Because none of these can be measured directly, they have throughout the history of geodesy been differently estimated by geodesists of various countries. The ellipsoid of reference plus the initial point of a geodetic network defines a distinctive datum. Any change or difference in any one of the dimensions of an ellipsoid or in the initial point changes the datum and the resultant geodetic system. The joining of two or more datums creates discrepancies at points common to the datums, as at a border between

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countries. The US uses the North American Datum, 1927, based on the Clarke ellipsoid of 1866. The Soviets use the Pulkovo Datum, 1942, based on the Krasovskiy ellipsoid of 1940. The joining of the datums of continents is further complicated by the lack of intervening triangulation over bodies of water (now corrected with HIRAN ties by the USAF), thus giving rise to errors in computing distances and directions between widely separated launch and target points for ICBM operations.

2. Fitting of the Ellipsoid to the Geoid

Because the earth is not a true sphere, and hence not a smoothed surface, mathematical difficulties (and discrepancies) arise in fitting the ellipsoid of reference, a mathematical approximation to the earth, to the geoid, a generalized, undulating representation of the sea-level earth surface. The latter cannot be observed directly but must be deduced from astronomic observations or from the measurement of random variations in the force of gravity from point to point on the earth's surface. Of these, only gravity can be measured on both land and sea; astronomic determinations at sea cannot be measured within better than a 1-mile error. The unknown angular separation between a geoid and an ellipsoid leads to angular errors -- deflection of the vertical -- since the plumb bob of surveying instruments is perpendicular to the geoid and not to the ellipsoid on which all computations are made. For very small countries it has been sufficient to assume that the geoid and ellipsoid were coincident; for others the errors could in some cases be corrected by astronomic methods. But, for a country as broad as the USSR, the errors were found to be inadmissible, amounting "to 40-50 times the errors of field work." In the 1930's the Soviets learned that the German ellipsoid then in use (Bessel) and the conventional western method of computation (development method) gave an error of some 900 meters (3,000 feet) in the positions of common points. As a result, a new ellipsoid was computed in 1940, and a new method of computation was adopted (projection method), in which points are projected perpendicular to the ellipsoid. The Soviets now assert that the inferiority of the development method will be felt sharply in the future when adjoining nets are connected and that divergencies will make cartographic unification impossible. Essential to the projection method are gravity data, for which the Soviets began systematic surveys in 1932. The technique of this method is similar to that used by the USAF in positioning Ascension Island to Cape Canaveral, in which an accuracy of ± 500 feet is claimed. The method is being used by the Soviets to establish geodetic positions in Antarctica on the Soviet ellipsoid, a part of the development of a Soviet world geodetic system.

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C. US Solutions

1. Two agencies in the US are concerned with the US geodetic problem -- the USAF Aeronautical Chart and Information Center and the US Army Map Service. [REDACTED]

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2. Army Map Service

The US Army Map Service effort of long standing has been directed to (a) the derivation of a new ellipsoid based initially on the classical astro-geodetic method; (b) an adjustment of various local datums of Europe, European USSR, and the peripheral areas of the USSR (including the Far East) into several continental, or preferred, geodetic systems; and (c) the derivation of an Army World Geodetic System.

3. USAF-ACIC

The USAF has also been engaged in the derivation of a USAF World Geodetic System based on a gravimetric approach. Toward this end, the USAF has undertaken independent programs for establishing intercontinental ties (HIRAN, solar eclipse, etc.). Within the past year the Army and USAF World Geodetic Systems have coordinated their results into a Defense World Geodetic System (DWGS). Nevertheless, much additional data as well as trans-Pacific ties will be needed before the DWGS will satisfy all target positioning requirements.

4. Intercontinental Connections

Although a number of important programs are underway, some -- such as HIRAN connections, the IGY lunar-photography program, satellite tracking, and ballistic-flare triangulation -- will provide information needed for cross-checking intercontinental ties and for effecting a direct connection between the Far East and North America. Others -- such as the world gravity survey -- will provide information that will significantly improve (a) the Defense World Geodetic System and (b) the accuracy of positioning submarine launch points for the Polaris missiles.

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5. The Map and Data Gap

The most serious gap in US target-positioning capabilities is the lack of modern Soviet topographic maps and geodetic and gravity catalogs. Without these the US will be seriously handicapped in deriving geodetic positions, especially of ballistic missile sites in areas for which neither topographic map coverage nor geodetic or gravity data are available. Such areas include the vast territory east of the Urals and north of the Trans-Siberian railway. For large portions of this area, it is still doubtful whether such sites could be located to within 1 nautical mile.

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D. Efforts Toward Map and Data Collection

1. Overt collection efforts for large-scale maps of the Sino-Soviet Bloc date back to World War II. There has been no success to date.

2. Growing awareness of the seriousness of this gap has led to elevating the collection requirements to top priority for the fulfillment of a First Category Priority National Intelligence Objective for precise geodetic location of critical targets (para. f).

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a. [REDACTED]

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[REDACTED] The closest possible coordination is maintained between the CIA and the Army, USAF, and Navy.

b. Some success has been achieved in map collection for East Germany, 13 map sheets at 1:25,000 having been obtained as a direct result of programmed collection and 102 through chance events [REDACTED]

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[REDACTED] No comparable map sheets have been obtained on the USSR proper or any other Bloc area.

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3. US scientists are being informed of existence of known catalogs to stimulate scientific pressure on Soviet Bloc scientists to release gravity data.

ORR/CIA

21 October 1960

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